Reprinted from
AMERICAN POTATO JOURNAL, JUNE, 1970, VOL. 47 — No. 6
pp. 214-224

CHEMICAL COMPOSITION OF POTATOES. VII RELATIONSHIP OF THE FREE AMINO ACID CONCENTRATIONS TO SPECIFIC GRAVITY AND STORAGE TIME[1]

EUGENE A. TALLEY AND WILLIAM L. PORTER[2]

ABSTRACT

Prior to storage, Maine-grown Katahdin potatoes were sorted into five specific gravity classes. Samples of three classes (high, intermediate, and low) were stored in individual boxes at 38 F for eight months, 45 F for one month, and 50 F for one month. New York-grown Katahdins were sorted into specific gravity classes periodically after removal from storage. Both lots were analyzed periodically for free amino acids (including the amides). In general, an inverse relationship was found between total solids and free amino acids calculated on a dry weight basis in Maine-grown and New York-grown Katahdin potatoes. In most cases little difference was found on the fresh-weight basis. Changes in the amino acids during storage were quite random. The differences found in the amino acid values between samples due to sorting for specific gravity before and after placing in storage were minor.

RESUMEN

Antes del almacenaje, las papas Katahdin provenientes de Maine fueron clasificaadas en cinco clases de gravedad específica. Muestras de tres clases (alta, intermedia y baja) fueron guardadas en cajas individuales a 38 F por ocho meses, 45 F por un mes y 50 F per un mes. Las Katahdins provenientes de Nueva York fueron removidas periodicamente de su almacenaje para su clasificación en grupos de gravedad específice e inmediato análisis.

Ambos lotes fueron analizados periódicamente para amino-ácidos libres (incluyendo las amidas). En general se encontró una estrecha relación inversa entre los sólidos totales y amino-ácidos libres, calculados sobre bases de peso seco en las papas de Maine y las de New York. En la mayoría de los casos se encontraron pequeñas diferencias sobre bases de peso fresco. Los cambios en los amino-ácidos durante el almacenaje se efectuaron al azar. Las diferencias encontradas en los valores de los amino-ácidos entre las muestras debidas a la clasificación para gravedad específica antes y después del almacenaje fueron menores.

Results from a previous study relating free amino acid concentration to storage time and specific gravity on potatoes grown in 1959 were reported in 1964 (Talley et al 5). For that study, the potatoes were separated into specific gravity classes at the time the samples were taken from storage for analysis. This led to changes in the relative proportions of the total sample in each class and some of the potatoes may have been in different classes at different sampling stages of the storage period, depending on where the specific gravity break between classes was made.

[1] Accepted for publication August 11, 1969.
[2] Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Philadelphia, Pennsylvania 19118.

The present study was undertaken to determine if previous results could be corroborated. To be sure that the tubers were in the same specific gravity class throughout the storage period, they were separated into specific gravity groups upon harvest and before placement in storage. Also reported are results obtained on some New York-grown Katahdin potatoes which were brine separated after storage.

Materials and Methods

Immediately after harvest at Aroostook Farms, Presque Isle, Maine in the fall of 1960, a lot of Katahdin potaoes was separated into five levels of specific gravity by use of glycerin solutions. The high, intermediate, and low fractions were selected for study. A description of the procedure and a general discussion of the relationships between specific gravity, solids, and the nitrogenous constituents have been reported (Fitzpatrick et al 2), as well as changes in the non-volatile organic acids (Schwartz et al 4). After thorough washing and drying, individual samples were stored at 38 F at the Maine Station. Samples of each level were sent to Philadelphia periodically for analysis. The temperature of storage was raised to 45 F for one month after 8 months of storage at 38 F and then to 50 F for another month to induce sprouting.

Concurrently, a study was carried out on 1960 New York-grown Katahdin potatoes furnished by the El-Ge Potato Chip Company, York, Pennsylvania. In this latter case, it was necessary to brine-separate the potatoes at the time of analysis instead of prior to placement in storage, and the storage temperature was varied in a different manner. After 2 months at 60 F, the temperature was gradually lowered, over a 30 day period, to 38 F. During the last week of the total 7-month storage period, the temperature was raised to 56 F.

More details on the treatment of both lots of potatoes and figures on the size of the fractions, total solids, nitrogen content, weight loss, and specific gravity may be found in reference 2. The same samples were used for the results reported here and in 2 and 4.

The alcoholic extracts were analyzed for amino acids by the Moore and Stein method as described previously (5), except that alkaline hydrolysis (Hirs et al 3) was used to convert the pyroglutamic acid to glutamic acid instead of the acid hydrolysis previously employed. This procedure, however, did not result in any marked improvement in the precision of the pyroglutamic acid analysis.

Results and Discussion

Since the results of this work are too voluminous for publication of the basic data, only the means of the storage data and of the specific gravity data are reported. The data for the neutral and acidic amino acid concentration means from the Maine samples are reported in Table 1 and the basic amino acid data in Table 2. The corresponding results for the New York grown samples are in Tables 3 and 4. For those interested in the original analytical data, copies of the six tables are available from the authors.

In general, two separate samples were carried through the entire extraction and analytical procedure. The amino acid data are reported as

TABLE 1.—*Means of amino acid concentrations, by storage period and specific gravity, for Maine Katahdin potatoes. Neutral and acidic amino acids*

Stored (mo.) Sp. gr. class Amino acid[2]	0	1	4	6	8	10	High	Medium	Low	CV[1] %	Sprouts
	Micromoles amino acid per gram potato (dry basis)										
Unk. #1	0.46a[3] A	0.52a A	0.58a A	0.54a A	0.52a A	0.53a A	0.52a A	0.52a A	0.54a A	25.7	1.40[4]
Unk. #2	0.57a A	0.54a A	0.63a A	0.62a A	0.59a A	0.63a A	0.49a A	0.64a A	0.68a A	36.2	1.05
ASP	13.57f F	21.16de DE	25.70abc ABC	27.27ab AB	23.89abcd BCD	27.44a A	20.01c A	23.07b A	26.43a A	12.8	11.80
THR	4.55d BCD	4.51d D	4.92bcd BCD	5.50ab ABC	5.45abc AB	5.64a A	4.30c A	5.11b A	5.88a A	10.6	2.17
SER	4.52d D	6.13abcd ABCD	6.99abc ABC	6.33abcd ABCD	7.69a A	7.42ab AB	5.75a A	6.67a A	7.14a A	22.0	12.94
ASN	153.95d CD	154.09d DE	148.25d E	170.20bc BC	177.58ab AB	181.40a A	141.41c B	161.36b B	189.97a A	4.4	64.70
GASN	209.43cd BC	211.54abcd ABCD	204.40d E	222.34abc BCD	225.76ab AB	232.72a A	191.36c A	215.22b A	246.52a A	5.9	115.40
PRO	16.64b B	15.03b B	15.61b B	16.44b B	16.84b B	21.49a A	13.16b B	18.14a A	19.72a A	14.7	174.33
GLU	19.33d D	17.04e E	20.18d D	22.96b B	21.65c C	25.69a A	20.74b A	20.71b B	21.96a C	4.4	18.52
GLY	2.24a A	2.09a AB	2.14a AB	1.97a B	2.14a AB	1.76a B	1.71c A	2.09b A	2.36a A	14.4	2.56
ALA	6.77a A	6.68ab B	5.08c C	4.83cd D	4.24cd E	3.89d E	4.63a A	5.06a A	5.72a A	14.8	3.37
Unk. #3	0.36a A	0.30abc BC	0.31ab AB	0.26bcd BCD	0.15e E	0.05f F	0.18b A	0.25a A	0.29a A	30.1	0.16

VAL	17.99a A	18.33a AB	16.98a BC	16.85a C	17.59a BC	17.36a ABC	14.24c B	17.67b A	20.61a A	6.4	11.67
MET	6.57a A	5.99b B	5.28c C	4.63de E	4.36e E	4.92cd CD	4.47c B	5.27b A	6.14a A	6.0	0.47
ILE	9.70a A	9.37a AB	7.96b C	7.61b C	7.99b C	7.78b C	6.90c C	8.35b B	9.95a A	7.5	5.06
LEU	4.28bc B	3.68d D	3.48d D	3.70d D	4.53ab BC	4.94a A	3.32c C	4.03b B	4.95a A	9.6	4.85
TYR	4.83d C	4.75d C	4.90cd C	5.40c C	6.14b B	6.87a A	4.82c A	5.44b A	6.18a A	9.9	0.92
PHE	7.53b ABC	7.01b D	6.85b D	7.22b D	8.56a AB	8.37a A	6.38c B	7.74b A	8.65a A	8.0	1.66
BAL	1.09b AB	1.31a A	0.92bc C	0.68d D	0.90c BC	0.54d D	0.77b A	0.93a A	1.02a A	18.2	0.21
PYR PO_4	40.43c E	46.53bc CDE	60.47abc ABCD	77.13a A	60.63abc ABC	64.93ab AB	45.23b B	55.60b AB	74.23a A	18.3	61.30
PYR	16.0 a A	12.7 a A	22.4 a A	13.4 a A	15.5 a A	16.0 a A	11.9 b B	13.1 b B	23.4 a A	51.3	33.6

[1]CV = Coefficient of variation, based on 36 values.

[2]Unk = Unknown, listed in order of emergence from column (5) and calculated as leucine equivalents; ASP = ASPartic acid; THReonine; SERine; ASN assumed to be asparagine only (determined after treatment to remove glutamine (5)); GASN contains ASparagiNe plus part of the Glutamine, calculated as asparagine (5); PROline; GLUtamic acid; GLYcine; ALAnine; VALine; METhionine (includes sulfoxides); ILE = IsoLEucine; LEUcine; TYRosine; PHEnylalanine; BAL = *Beta* ALanine; PYR, PO_4 = glutamine treated to convert all of it to PYRoglutamic acid before determination (5); PYR = glutamine spontaneously converted to PYRoglutamic acid before determination.

[3]Means followed by the same letter are not significantly different from each other at the 5% level; lower case letters refer to dry basis and capitals refer to fresh basis. The means are based on 2x3 values for storage periods and 2x6 values for specific gravity. Significance was determined by Duncan's multiple range procedure (1).

[4]The 10th-month samples were desprouted before extraction. The resulting sproouts were combined into one sample and the means of replicate determinations are reported here.

TABLE 2.—*Means of amino acid concentrations, by storage period and specific gravity, for Maine Katahdin potatoes. Basic amino acids.*

Stored (mo.)	0	1	4	6	8	10					
Sp. gr. class							High	Medium	Low	CV[1]	
Amino acid[2]	Micromoles amino acid per gram potato (dry basis)									%	Sprouts
GAM	23.86a[3] A	20.30c C	20.62c C	20.52c C	23.60ab AB	21.33abc BC	21.5 a A	21.4 a B	22.2 a B	9.7	7.08[4]
ORN	0.25e E	0.37d D	0.37d D	0.56abc ABC	0.58ab AB	0.60a A	0.38b A	0.43b A	0.55a A	17.7	0.24
ETH	0.25a A	0.39a A	0.39a A	0.49a A	0.56a A	0.46a A	0.29b B	0.43b B	0.67a A	46.7	1.03
NH_3	11.63d D	12.10d D	12.72d D	17.70abc ABC	20.20a AB	19.97ab A	11.25c B	16.12b A	19.79a A	19.3	51.15
LYS	6.78a CD	5.88a D	7.12a CD	7.98a C	9.15a AB	9.91a A	6.66a A	7.71a A	9.04a A	12.2	5.69
HIS	4.21c E	4.27c E	5.78b BCD	6.30ab BC	6.35ab B	7.45a A	4.85b A	5.89ab A	6.43a A	17.8	1.98
Unk. #4	1.35a A	1.36a A	1.31a A	1.20a A	1.40a A	1.79a A	1.21b A	1.35b A	1.66a A	22.6	1.98
ARG	14.18d C	14.01d C	14.41d C	21.99bc B	23.73ab AB	26.79a A	16.07b A	18.42b A	23.07a A	23.2	6.32
Total N	1385.0 e B	1451.6 d B	1487.2 cd B	1639.7 a A	1513.2 bc B	1546.5 b A	1291.3 c B	1498.1 b A	1722.3 a A	2.7	2225.2
Extr. N	790.7 d C	838.2 cd C	874.3 bc BC	873.8 bc BC	915.1 ab B	962.3 a A	747.0 c B	880.3 b A	999.9a A	5.6	1082.5
Solids, %	21.94 A	20.94 C	20.51 D	20.51 D	20.66 D	21.28 B	23.07 A	21.11 B	18.74 C	1.1	12.65
Spec. Grav.	1.08503 A	1.08363 AB	1.08577 A	1.08517 A	1.08120 B	1.08553 A	1.09378 A	1.08462 B	1.07477 C	0.2	......

[1]See under Table 1.
[2]GAM = *GAMma*-aminobutyric acid; ORNithine; ETHanolamine; NH_3 = ammonia; LYSine; HIStidine; Unk. #4 may be tryptophan but is calculated as leucine equivalents; ARGinine; TOTAL N is total nitrogen by Kjeldahl; EXTR. N is nitrogen in alcoholic extracts by Kjeldahl; Solids % = Solids in percent as determined by oven drying; Spec. Grav. = Specific gravity of potato samples.
[3]See under Table 1.
[4]See under Table 1.

micromoles of amino acid per gram of dry weight of potato. Percent solids data are included; thus the composition on a fresh weight basis may be calculated.

Since the values were not available when reference 2 was written, the means and significant differences for solids, specific gravity, total nitrogen, and extractable nitrogen are included in Tables 2 and 4.

The coefficients of variation (CV) listed in Tables 1 to 4 tended to be high where the constituent was present in low concentrations, e.g., the unknowns, ETH, ORN, etc. Pyroglutamic acid has an extremely high coefficient of variation because the analytical method is less precise than that for the usual amino acids, and the results are a measure of the decomposition of glutamine during extraction and concentration. Other amino acids having high CV values, such as serine, proline, ammonia, histidine, etc., may be more sensitive to uncontrolled factors such as soil differences, etc. Tubers from a single variety grown in a single field and even two tubers from a single hill do show fairly large differences.

The patterns of differences due to storage periods are similar on the dry and wet bases. The minor differences which do occur are probably due to differences in solids content. As reported in the previous publication (5) with minor exceptions, the variations of amino acid content with storage time are not very significant. Alanine, which decreased with time, was the only amino acid showing a definite trend. Proline showed the opposite trend but a significant increase was indicated only in the last storage period. In other cases, significant differences were found but the changes between periods were more or less random. In the New York group, alanine showed a definitely decreasing trend and arginine definitely increased. In both cases, the differences between the first two periods were not significant. No statistically significant differences were found in five components for the Maine-grown samples and in seven for the New York-grown samples. Most had high CV values except GLY, VAL, and GAM in the New York group. In this group the number of storage periods is smaller and the storage temperature was not constant. These conditions may explain part of the differences between the two groups.

On the dry basis, the trend was for the amino acid content to decrease with increase in specific gravity. Twelve cases of the Maine-grown and three cases of the New York-grown potaoes showed significant differences among all three levels of specific gravity. (The increased significance among the differences found in the Maine group may indicate increased precision if the samples are specific gravity graded before storage). In ten and 17 cases, respectively, one level was significantly different from the other two. *GAMma*-aminobutyric acid has been consistent in showing no significant difference between specific gravity groups on the dry basis. The extraneous variation was quite high for many of the others, showing little significant difference.

Consistent with results in previous publications (2, 5), the amino acid and nitrogen contents on the fresh basis tended not to vary with specific gravity. In the Maine group, three exceptions stand out. GLUtamic acid was highest in the low specific gravity class and IsoLEucine and LEUcine were highest in the high specific gravity class. PROline was the only one different in all specific gravity levels in the New York group and was highest in the high specific gravity class.

TABLE 3.—*Means of amino acid concentrations, by storage period and specific gravity, for New York Katahdin potatoes.*

Neutral and acidic amino acids.

Stored (mo.) / Sp. gr. class / Amino acid[2]	1	2	4	6	High	Medium	Low	CV[1] %
	Micromoles amino acid per gram potato (dry basis)							
Unk. #1	0.73a[3] A	0.65a A	0.75a A	0.53a A	0.53b A	0.56b A	0.87a A	31.2
Unk. #2	0.45a A	0.54a A	0.53a A	0.45a A	0.44b A	0.54a A	0.52ab A	15.5
ASP	26.93b B	30.41a A	26.16b B	27.06b B	25.62b A	28.09a A	29.20a A	6.5
THR	5.07b B	5.19ab B	5.63ab AB	5.76a A	4.85b A	5.34b A	6.04a A	8.6
SER	7.58b B	9.25ab AB	10.68a A	9.18ab AB	8.33b A	9.10ab A	10.09a A	15.0
ASN	179.46b B	163.61c B	179.56b B	195.08a A	165.70b A	173.89b A	198.69a A	3.9
GASN	214.33b BC	229.49a B	232.12a B	242.03a A	211.38c A	225.51b A	251.58a A	5.0
PRO	32.35b C	39.49a A	34.64ab ABC	37.94ab AB	40.18a A	36.24ab B	31.88b C	13.2
GLU	22.39b B	21.70b B	25.69a A	20.93b B	22.26a A	23.01a A	22.79a B	6.9

GLY	2.28a A	2.41a A	2.37a A	2.41a A	2.07b A	2.38a A	2.58a A	10.2
ALA	9.16a A	9.14a A	7.53b B	3.74c C	6.39b B	8.01a A	7.78a B	7.0
Unk. #3	0.52b B	0.72a A	0.86a A	0.42b B	0.62a A	0.66a A	0.61a A	22.4
VAL	23.02a A	22.41a A	22.20a A	21.73a A	21.40b A	21.92ab A	23.79a A	8.4
MET	8.51a A	7.40b B	6.44c C	6.79c BC	6.48c A	7.13b A	8.25a A	6.2
ILE	13.29a A	11.60b B	11.45b B	10.35b B	10.68b A	11.47b A	12.86a A	8.8
LEU	5.51a A	4.72b B	4.86ab AB	4.94ab AB	4.71b A	5.00ab A	5.32a A	9.7
TYR	5.31b B	5.13b B	6.10ab AB	6.78a A	5.52a A	5.60a A	6.37a A	17.1
PHE	10.57a AB	10.17a B	10.64a AB	11.47a A	10.78a A	10.44a B	10.92a B	9.6
BAL	1.25a A	1.20a A	1.00a A	1.23a A	0.90b B	1.10ab AB	1.50a A	28.6
PYR PO_4	41.37b B	42.23b B	57.47ab AB	66.77a A	48.33ab A	43.55b A	64.00a A	18.2
PYR	18.3 a A	7.0 b B	8.5 b B	8.3 b B	8.5 a A	11.4 a A	11.8 a A	40.6

[1]CV = Coefficient of variation, based on 24 values.
[2]See under Table 1.
[3]See under Table 1 (based on 2x4 values for specific gravity).

TABLE 4.—*Means of amino acid concentrations, by storage period and specific gravity, for New York Katahdin potatoes. Basic amino acids.*

Stored (mo.) / Sp. gr. class / Amino acid[2]	1	2	4	6	High	Medium	Low	CV[1] %
	Micromoles amino acid per gram potato (dry basis)							
GAM	19.5 a[3] A	18.9 a A	18.5 a A	19.8 a A	18.4 a A	20.0 a A	19.2 a B	7.5
ORN	0.34b C	0.42b ABC	0.69a AB	0.72a A	0.55a A	0.57a A	0.62a A	40.0
ETH	0.38a B	0.45a AB	0.46a AB	0.53a A	0.41a A	0.45a A	0.50a A	23.2
NH_3	4.64c C	12.34b B	11.90b B	18.35a A	8.08c B	12.28b A	15.06a A	19.0
LYS	9.68b B	8.42c B	9.51bc B	10.84a A	8.91b A	9.14b A	10.79a A	9.0
HIS	5.59b B	5.70b B	5.88b B	7.43a A	5.36b A	5.86b A	7.24a A	11.0
Unk. #4	1.19a A	1.28a A	1.39a A	1.27a A	1.16a A	1.33a A	1.36a A	28.0
ARG	17.10c C	17.40c C	20.70b B	26.52a A	20.52ab A	18.81b B	21.97a B	9.2
Total N	1593.9 b C	1530.6 c D	1624.7 a B	1621.6 ab A	1497.9 c A	1562.0 b B	1718.4 a B	1.4
Extr. N	937.0 b B	936.2 b B	988.9 a A	992.6 a A	920.0 b A	937.0 b B	1034.0 a B	2.7
Solids, %	19.79 BC	20.06 B	19.88 BC	20.43 A	21.86 A	20.08 B	18.18 C	1.2
Spec. Grav.	1.07633 C	1.07883 B	1.07973 B	1.08303 A	1.08773 A	1.07888 B	1.07185 C	0.1

[1]See under Table 3.
[2]See under Table 3.
[3]See under Table 3.

In general, the changes repeat the pattern found previously (2, 5); the differences with storage time are relatively minor. The difference in the case of alanine may be real — a decrease with storage time. PROline shows a less definite trend than previously towards an increase with storage. This increase is more marked when sprouting is about to begin. ARGinine is even less definite, with a trend indicated in only two of the groups — 1959 Maine and 1960 New York.

The amino acid contents on the fresh basis tended to be constant between specific gravity groups. PROline is the only amino acid to show significant differences in all classes in more than one crop. It was highest in the low specific gravity class in the 1959 Maine and the 1960 New York crops. The increase in precision of the Maine 1960 study may have shown up in the fact that on the fresh basis, the concentrations of GLUtamic acid, IsoLEucine and LEUcine differed among the three classes. These differences were not apparent in the other two crops. On the other hand, the amino acid content on the dry basis tended to increase as the specific gravity decreased. Thus, the increase in specific gravity is due to increase in solids not amino acids, probably starch. The definite exception, *gamma*-aminobutyric acid, showed no significant difference on the dry basis for all three crops which reflects a decrease on a fresh weight basis. However, in the two Maine crops, a considerable (more or less random) variation was noted from one period to the next which probably cancelled effects due to specific gravity.

In general, the changes repeat the patterns found for the previous year. Amino acid content varied little with storage time but varied inversely with specific gravity. Any changes noted during storage must be accounted for by other factors than storage, such as sampling or changes in temperature. Both methods of sorting into specific gravity classes produce similar results but experimental precision may be increased slightly by sorting prior to storage.

It must be pointed out that amounts of amino acids present in potato tubers may be quite different in lots from different growing locations and from different years. For example, the amount of PROline was about three times greater in the 1960 crop and about three times greater still in the New York-grown Katahdins than in the Maine-grown Katahdins harvested in 1959. Changes in compositon with variety, location and year of growth are the subjects of a later study.

Acknowledgments

The authors wish to express appreciation to Mr. J. W. Garvin, Mr. G. H. Eppley, and Mr. R. O. Pierce for carrying out the many tedious extractions, to Dr. T. J. Fitzpatrick for determining solids contents, to Mr. Joe N. Boyd and other members of the Biometrical Services group for the statistical study of the results, to the El-Ge Potato Chip Company, York, Pennsylvania for its generosity in providing the New York-grown Katahdins, to Dr. Hugh J. Murphy of the University of Maine for supplying the Maine Katahdins and to Mr. G. H. Eppley and Miss Ann T. Kiry for assistance in the calculation of the many amino acid results.

Literature Cited

1. Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11: 1-42.

2. Fitzpatrick, T. J., E. A. Talley, W. L. Porter and H. J. Murphy. 1964. Chemical composition of potatoes. III. Relationships between specific gravity and the nitrogenous constituents. Amer. Potato J. 41: 75-81.
3. Hirs, C. H. W., S. Moore and W. H. Stein. 1956. Peptides obtained by tryptic hydrolysis of performic acid-oxidized ribonuclease. J. Biol. Chem. 219: 623-642.
4. Schwartz, J. H., Reba B. Greenspun and W. L. Porter. 1966. Chemical composition of potatoes. V. Further studies on the relationship of organic acid concentrations to specific gravity and storage time. Amer. Potato J. 43: 361-366.
5. Talley, E. A., T. J. Fitzpatrick and W. L. Porter. 1964. Chemical composition of potatoes. IV. Relationship of the free amino acid concentrations to specific gravity and storage time. Amer. Potato J. 41: 357-366.